

Description

INTEGRATED PRESSURE CONTROL SYSTEM FOR WORKPIECE CARRIER

FIELD OF INVENTION

[0001] The present invention generally relates to the art of planarizing a workpiece against an abrasive surface and, more particularly, to an integrated pressure control system for a workpiece carrier that applies pressure to the back surface of a workpiece during planarization.

BACKGROUND OF THE INVENTION

[0002] The manufacture of many types of workpieces requires the substantial planarization of at least one surface of the workpiece. Examples of such workpieces that require a planar surface include semiconductor wafers, optical blanks, memory disks, and the like. Without loss of generality, but for ease of description and understanding, the following description of the invention will focus on applications to only one specific type of workpiece, namely a semiconductor wafer. However, the invention is not to be

interpreted as being applicable only to semiconductor wafers.

[0003] In an exemplary conventional method for planarizing a wafer, the wafer is secured in a carrier that is connected to a shaft in a chemical mechanical polishing (CMP) tool. The shaft transports the carrier, and thus the wafer, to and from a load or unload station and a position adjacent a polishing pad mounted to a platen. A pressure is exerted on the back surface of the wafer by the carrier in order to press the wafer against the polishing pad, usually in the presence of a slurry. The wafer and/or polishing pad may be rotated, orbited, linearly oscillated or moved in a variety of geometric or random patterns via motors connected to the shaft and/or platen.

[0004] The construction of the carrier head and the relative motion between the polishing pad and the carrier head have been extensively engineered in an attempt to achieve a uniform or controlled non-uniform removal of material across the surface of the workpiece and hence to achieve the desired planar surface. For example, numerous carrier designs are known in the art for holding and distributing a pressure on the back surface of the wafer during the planarization process. Conventional carriers commonly have

a hard flat pressure plate that is used to press against the back surface of the wafer. As a consequence, the pressure plate is not capable of applying a uniform polish pressure across the entire area of the wafer, especially at the edge of the wafer. In an attempt to overcome this problem, the pressure plate is often covered by a soft carrier film. The purpose of the film is to transmit uniform pressure to the back surface of the wafer to aid in uniform polishing.

[0005] Other conventional carriers implement means for applying more than one pressure region across the back surface of the wafer. Specifically, some conventional carriers provide a carrier housing with a plurality of concentric internal chambers that may be independently pressurized separated by barriers. By pressurizing the individual chambers in the top plate to different magnitudes, a different pressure distribution can be established across the back surface of the wafer. The pressure control systems used to operate these multi-zone carriers utilize a design in which the pressure control components, such as pressure regulators and transducers, are located remotely from the carriers on a dedicated pneumatic panel. The regulators and transducers are connected to the different chambers in the multi-zone carriers via long, narrow pneumatic tubes

through a multi-port rotary union. However, this architectural design creates a number of problems.

[0006] First, significant drops in pressure can occur across the pressure lines during employment of the pressure control system. Second, there is a large response time or lag time in communicating and correcting for pressure drops in the lines. Third, the pneumatic rotary union through which the pressure lines are routed lacks reliability. Fourth, the system is more vulnerable to leaks between channels and leaks from channels to the environment/atmosphere outside the channels. Fifth, the pressure control system lacks the ability to measure pressure at the point of use, namely in the chamber of the carrier, and therefore lacks the ability to utilize a closed loop control design.

[0007] All of the above problems cause existing pressure control systems to be plagued with three major deficiencies. These deficiencies include low dynamic accuracy, poor static accuracy, and loss of control at low pressure levels. Accordingly, there is a need for a workpiece carrier having an integrated pressure control system that is capable of overcoming these major deficiencies.

SUMMARY OF INVENTION

[0008] The present invention is directed to a workpiece carrier

for planarizing a workpiece having an integrated pressure control system for applying pressure to the back surface of a workpiece or wafer. All components for executing the regulation of pressure to the backside of the wafer are mounted on a common manifold which is connected to, or comprises part of, the carrier's housing. These components include, but are not limited to pressure transducers and control valves.

[0009] One exemplary embodiment of a workpiece carrier housing in accordance with the present invention includes a carrier housing, a workpiece bladder coupled to the housing so that a surface of the workpiece bladder can press against a back surface of the workpiece, and at least one pressure transducer mounted to the carrier housing for monitoring pressure to the workpiece bladder.

[0010] In one aspect of the invention, the workpiece bladder may comprise a number of zones that can be pressurized individually with each zone having a pressure transducer for monitoring pressure to that zone. In another aspect of the invention, there is at least one valve mounted to the carrier to manipulate air flow to the workpiece bladder.

[0011] In yet another aspect of the invention, a control board may be mounted to the carrier for controlling the compo-

nents which regulate pressure provided to the workpiece bladder. Further, in still another aspect of the invention, the workpiece carrier may include one or more automatic calibration means for calibrating any pressure transducers located on the carrier.

[0012] Another exemplary embodiment of the present invention includes an integrated pressure control system for planarizing a workpiece which has a multizone workpiece carrier with a plurality of pressurizable zones and a pressure control system mounted to the carrier for controlling the pressure that is provided to the multiple pressurizable zones. The pressure control system may include at least one pressure transducer and at least one valve. The pressure control system may also comprise an automatic calibration system and a rotary union for connecting electrical lines to the pressure control system. The rotary union may also function to connect an air supply line and an air exhaust line to the pressure control system.

[0013] Yet another exemplary embodiment of the invention is directed to a carrier insert for a multizone workpiece carrier which includes a pneumatic manifold having a plurality of ports that are aligned with multiple pressurizable zones located in the multizone workpiece carrier and at least

one pressure transducer mounted to the pneumatic manifold for directing pressure through the ports. The carrier insert may also include at least one valve mounted to the pneumatic manifold and a control board mounted to the pneumatic manifold.

BRIEF DESCRIPTION OF DRAWINGS

[0014] The present invention is hereinafter described in conjunction with the appended drawing figures, wherein like numerals denote like elements, and in which:

[0015] FIG. 1 is a schematic of a pressure control system known in the prior art;

[0016] FIG. 2 is a schematic of an exemplary integrated pressure control system in accordance with the present invention;

[0017] FIG. 3 is a more detailed schematic of another embodiment of the exemplary integrated pressure control system of the present invention;

[0018] FIG. 4 is a partial perspective view of a workpiece carrier containing components of the integrated pressure control system of the present invention;

[0019] FIG. 5 is a cross-sectional view of a workpiece carrier containing the integrated pressure control system of the present invention; and

[0020] FIG. 6 is a top plan view of a workpiece carrier containing

the integrated pressure control system of the present invention.

DETAILED DESCRIPTION

[0021] Preferred embodiments of the present invention include integrated pressure control systems for wafer carriers used in planarizing wafers where the components for controlling pressure applied to the back surface of a wafer are contained on the carrier itself. The present invention is particularly suited for multizone carriers which contain multiple zones for applying varying degrees of pressure to different areas of the back surface of the wafer. The carrier remains a separate hardware component for CMP where the integrated pressure control system may be snapped to the carrier during mounting of the carrier. Alternatively, the pressure control system of the present invention may be integrated into the structure of the carrier such that it is not removable from the carrier.

[0022] The present invention may be used with a variety of CMP tools such as, for example, the AvantGaard 676, 776 or MV200 or Auriga C or CE or MV300 made commercially available by Novellus (formerly SpeedFam-IPEC) located in Chandler, Arizona. The present invention may also be used with a variety of workpiece or wafer carriers, and es-

pecially multizone carriers such as those described in U.S. Patent Nos. 6,390,905 and 6,336,853 and 6,508,694.

CMP tools that may be used to practice the invention are well known in the art and will not be discussed in detail to avoid confusing the invention. It should also be understood by those skilled in the art that wafer carriers that are well known in the art may be used to practice the invention and that such wafer carriers may be provided with a removable integrated pressure system or may be singularly reconfigured and recreated to provide a one piece wafer carrier that incorporates an integrated pressure control system.

[0023] A wafer carrier in a CMP tool must retain the wafer and assist in the distribution of a pressing force on the back of the wafer while the front of the wafer is planarized against an abrasive surface. The abrasive surface typically comprises a polishing pad wetted by chemically active slurry with suspended abrasive particles. The preferred polishing pad and slurry are highly dependent on the particular process and workpiece being used. Conventional CMP polishing pads and slurries are made commercially by Rodel Inc. from Newark, Delaware for typical applications.

[0024] Exemplary embodiments of the present invention will be

discussed in detail with reference to a multizone carrier, i.e. a wafer carrier having a plurality of pressurizable zones for contacting the back surface of a wafer during CMP. A prior art pressure control system 10 for use with a multizone carrier 12 is shown in FIG. 1. Prior art pressure control systems are not integrated with the wafer carrier and typically include multiple channels 14, such as long pneumatic tubes, which are connected to multizone carrier 12. The number of channels 14 connected to carrier 12 is equal to the number of pressurizable zones contained in carrier 12. Pressure regulators 16 and pressure transducers 18 for each channel 14 are located remotely from carrier 12 and connected to control system 20. Pressure control components such as pressure regulators 16 and pressure transducers 18 are in turn connected to multizone carrier 12 through a multi-port rotary union 22. Multi-port rotary union 22 contains as many ports as there are channels 14.

[0025] Prior art pressure control systems such as that shown in FIG. 1 possess a number of problems such as experiencing significant pressure drop across channels 14 and a large response or lag time between signaling a change in pressure and actual change in pressure of a pressurizable

zone connected to a given channel 14. In addition, the reliability of pneumatic rotary union 22 is low due to the number of channels 14 passing there through and leaks between the channels and from the channels are also more likely to occur due to their location and the increased number of them passing through rotary union 22. The inability of prior art system 10 to measure the pressure at the point of use, i.e. in the chamber of the carrier, also delays response time and efficiency in changing or adjusting pressure within the zones in multizone carrier 12. The present invention was designed to overcome these problems.

[0026] A schematic of an exemplary integrated pressure control system in accordance with the present invention is shown in FIG. 2. Integrated pressure control system 30 includes a multizone carrier 32 having a multi-port manifold 33 for association with multiple channels 34. Multi-port manifold 33 includes multiple inlet valves 35 and exhaust valves 37 such that an inlet valve 35 and exhaust valve 37 are each paired with a separate zone 34 for pressurizing that zone. Multiple pressure transducers 38 are also contained on multi-port manifold 33 so that a pressure transducer 38 is coupled with each pair of inlet and ex-

haust valves 35 and 37 for controlling the pressure flow by inlet and exhaust valves 35 and 37. Inlet valves 35, exhaust valves 37, and pressure transducers 38 are all connected to a control board 44 located on multizone carrier 32. Control board 44 functions to send and receive electrical signals for controlling the pressure provided to separate zones 34 through their respective inlet and outlet valves 35 and 37.

[0027] Each inlet valve 35 located within carrier 32 is connected to a single pressure line 46 and each exhaust valve 37 located within carrier 32 is connected to a single exhaust line 48. Single pressure line 46 and single exhaust line 48 exit carrier 32 and are coupled to a pressure source and vacuum source, respectively, through rotary union 42. Rotary union 42 is connected to a control system 40 which commands and monitors pressure in a zone of the carrier. Control board 44, which manipulates inlet valves 35 and exhaust valves 37, is connected to rotary union 48 so that electrical signals may pass to and from control system 40 and to and from control board 44 via rotary union 42.

[0028] Integrated system 30 overcomes the problems and deficiencies present in prior art system 10. More specifically, the components responsible for air flow manipulation

such as valves, flappers, and variable orifices, are located at the carrier chamber thereby eliminating dynamic control error, air leaks, and differential pressure drop. Further, relocation of pressure transducers 38 to the carrier 32 in integrated system 30 improves static accuracy and linearity. Rotary union 42 is used to connect pressure line 46 and exhaust line 48 to carrier 32. The elimination of multiple pneumatic lines through a rotary union for each chamber 34 in carrier 32 eliminates the effects that potential leaks and pressure drops in these lines would have on system operation and performance. Potential leaks and pressure drops in main pressure line 46 and main exhaust line 48 are not critical for system operation since pressure supplied to chambers 34 is controlled at carrier 32. Rotary union 42 is also used to connect electrical lines between control system 40 and control board 44. The reliability and simplicity of this connection is much higher than for pneumatic lines. Finally, the reduced number of components in system 30 and their reduced dimensions, along with the simplified design for rotary union 42, allow for a greater number of channels and pressurizable chambers in multiple carrier 32, which in turn improve process performance of carrier 32.

[0029] FIG. 3 shows more detailed schematic of another embodiment of the integrated pressure control system of the present invention. Integrated pressure control system 50 includes a carrier head 52 having a plurality of inlet valves 55, a plurality of exhaust valves 57, and a plurality of pressure transducers 58 all located on carrier head 52. Carrier head 52 has multiple pressurizable chambers 54 where each chamber 54 is paired with an inlet valve 55, and exhaust valve 57, and a pressure transducer 58 each of which are electrically connected to a rotary union 70. Rotary union 70 is located on an outer top surface of carrier head 52 and connects control board with pressure control components located on carrier head 52.

[0030] A pressure supply source 67 is connected to main pressure line 66 which is coupled to multiple pressure lines contained in carrier head 52 via rotary union 72. A vacuum source 74 is connected to main vacuum line 76, which is in turn connected to multiple exhaust valves 57 located on carrier head 52 via rotary union 72. Under normal operation the pressure transducer 58 senses pressure in the particular chamber and sends electric signal to the control board via rotary union 70. This signal is compared with commanded pressure. If chamber pressure is larger

than commanded the control board, according to the control algorithm, preferably PID, commands inlet valve 58 to close and exhaust valve 57 to open. If chamber pressure is lower than commanded the control board commands inlet valve 58 to open and exhaust valve 57 to close. In the preferred embodiment the inlet and exhaust valves are proportional valves, meaning that the air flow through the valve is proportional to the signal commanded to the valve. This ensures smooth pressure control without fluctuations.

[0031] Exhaust valves 57 are connected to the source of vacuum. This allows to supply and control vacuum in the carrier chamber. Controlled vacuum is used in the carrier during wafer acquiring (wafer chuck).

[0032] A partial perspective view of an exemplary workpiece carrier containing the components of the integrated pressure control system of the present invention is shown in FIG. 4. Integrated pressure control system 80 includes a multi-zone carrier head having a wafer head mount plate 82 and a multi-port pneumatic manifold 84. Wafer head mount plate 82 and multi-port pneumatic manifold 84 are rigid and cylindrical in shape and may comprise, for example, stainless steel to give the multizone carrier the necessary

rigidity and resistance to corrosion needed in a CMP environment. Wafer head mount plate 82 may be adapted to be connected to almost any conventional CMP tool. Most conventional CMP tools have a movable shaft for transporting a carrier containing a wafer. The movable shaft typically allows the carrier to move between a wafer loading and/or unloading station and a position in proximity and parallel to an abrasive surface in the CMP tool.

[0033] Multi-port manifold 84 has multiple pressure transducers 88 and multiple control valves 90 located thereon so that a pressure transducer 88 and control valve 90 are associated with each pressurizable zone contained in the carrier. Although the present invention has been described as an integrated pressure control system for a multizone carrier, the present invention is also intended to include an integrated pressure control system for a carrier having a single pressurizable zone or chamber where the pressure control components for that chamber are located on the carrier. It will also be understood by those skilled in the art that multi-port manifold 84 may comprises an interchangeable piece that can be incorporated into existing carrier heads known in the art. In addition, the integrated pressure control system of the present invention is in-

tended to include any carrier head or pressure system where at least any one pressure control component is located on the carrier head.

[0034] FIG. 5 shows a cross-sectional view of the present invention which includes a workpiece carrier having an integrated pressure control system. The multizone carrier 100 includes wafer head mount plate 102 and multi-port pneumatic manifold 104. Multi-port pneumatic manifold 104 includes a plurality of pressure transducers 108, a plurality of control valves 110, and a plurality of pneumatic fittings 112 which connect pressure transducers 108 and control valves 110 to a wafer module plate 114. Carrier bladder 116 forms a plurality of pressurizable zones, each of which has an inlet port, an exhaust port, a pressure transducer, and inlet and exhaust control valves associated therewith.

[0035] The configuration of the integrated pressure control system of the present invention allows for automatic calibration of the system. Special calibration fixtures and one external high accuracy pressure transducer can be used to evaluate the performance of each individual channel and pressurizable chamber. Miscalibration of very channel can be estimated during calibration and specific calibration

coefficients can be stored in the memory of the CMP tool and applied during regular operations.

[0036] A top plan view of a workpiece carrier containing the integrated pressure control system of the present invention is shown in FIG. 6. The multi-zone carrier head 120 includes a multi-port pneumatic manifold 124 which contains a plurality of pressure transducers 128 and a plurality of control valves 130. A control board 144 for controlling pressure transducers 128 and control valves 130 is also located on multi-port pneumatic manifold 124.

[0037] The present invention redesigns the traditional multi channel pressure control system used with multizone carriers by relocating one or more pressure control components for the various pressurizable zones onto the carrier itself. The integrated pressure control system of the present invention eliminates a number of critical deficiencies associated with prior art pressure control systems, enables a significant increase in the number of control channels for controlling pressure to pressurizable zones, and allows for automatic calibration and evaluation of the system.

[0038] Although the foregoing description sets forth preferred exemplary embodiments and methods of operation of the

invention, the scope of the invention is not limited these specific embodiments or described methods of operation. Many details have been disclosed that are not necessary to practice the invention, but have been included to sufficiently disclose the best mode of operation and manner and process of making and using the invention. Modification may be made to specific form and design of the invention without departing from its spirit and scope as expressed in the following claims.